Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

Neural Network Model for Detecting a Partial Flow Blockage in an Assembly through Temperature Fluctuation in the Upper Plenum of KALIMER

S.H. Seong, Hae-Yong Jeong, S. Hur and S.O. Kim
Korea Atomic Energy Research Institute
shseong@kaeri.re.kr

1. Introduction

If a flow blockage in an assembly of a liquid metal reactor has occurred, then it will probably effect the integrity of the fuel assembly at the initiating stage and finally it could result in a cooling deficiency of the core. Therefore, it is important to detect a flow blockage in an assembly at early stage. Although no significant temperature increase in the upper plenum is expected at an early stage of the event, the characteristics of the temperature fluctuations in the upper plenum will be changed by the change of the temperature profile at the exit of the assembly.[1,2] So, the characteristics of the temperature fluctuations in the upper plenum could provide information about a partial blockage of an assembly in liquid metal reactors.

For investigating characteristics of the temperature fluctuations in the upper plenum of a whole core, we have numerically analyzed the fluctuating temperature field in the upper plenum beyond the exit of the assemblies in a reactor core by the LES (Large Eddy Simulation) turbulence model in CFX-5.7.[3]

After analyzing the temperature fluctuations in the upper plenum with various blockage conditions, we studied their statistical characteristics of the fluctuation data. Then, we developed a detection algorithm based on the feed-forward neural network model with the changes of the statistical parameters of the fluctuation data as inputs and the size and the location of the blockage conditions as outputs. Through learning and validating the neural network model, we suppose that the developed neural network model is proven to be an alternative to detect a partial flow blockage in an assembly of a liquid metal reactor.

2. Characteristics of Temperature Fluctuation

We analyzed the temperature fluctuation in the breakeven 1/6 upper plenum and 1/6 core to save on computation efforts because the core had a symmetric breakeven structure in an angular direction of 60° degree. Also, we analyzed the temperature fluctuation in the upper plenum in case that the hottest assembly (target assembly) was partially blocked with cases of reduced flow and not reduced flow conditions that were assumed by the blockage characteristics such as the shape and location and so on.[4]

For clearly representing the characteristics of the temperature fluctuation of each case, we introduced some statistical analyses such as the mean, the standard deviation, the skewness and the kurtosis of the temperature fluctuation data. Fig. 1 shows the statistical analysis results of the temperature fluctuations data during 2 sec along the axial direction at the center of the target assembly.

We found that the changes of the root mean square of the temperature fluctuation data had relationships with the size and flow rate of each blockage condition as well as the changes of its skewness and standard deviation was affected by the size and the location of the flow blockage. However, the kurtosis was nearly independent of the blockage conditions.

3. Neural Network Model

From the analogy in Section 2, we found the possibility of detecting a partial flow blockage in an assembly from the relationships between the partial blockage conditions and the statistical parameters. We introduced a neural network model which could identify the nonlinear relationships between various parameters. We designed the two hidden-layered neural network model of a learning algorithm with the scaled conjugate gradient.[5] The inputs of the neural model were the change of the root mean square, the stand deviation and the skewness between the variously assumed blockage conditions and the normal condition. The outputs of the model were the location (center, middle, edge) and the size (1%, 5%, 10%, 17.8%) of the various blockage conditions. The two hidden layers consisted of 7 neurons and one bias neuron in each layer. Figure 2 shows the structure of the neural network model and the hyperbolic tangent function was used as an activation function of each neuron. Figure 3 shows the results of learning. As shown in the figure, the model had a good capability to retrieve the location and the size of the blockage conditions.

For validating the developed neural model, we analyzed the new blockage conditions that were not used in learning the developed neural model. The locations and the sizes of new blockage conditions for validation were retrieved by the neural model. Figure 4 shows the target value and the retrieved values by the model from the blockage conditions of validation cases. The results showed a good agreement with all the validation cases. So, the developed neural network model was proven to be a good alternative for detecting a partial flow blockage in an assembly of a liquid metal reactor.

5. Conclusions

We have developed a neural network model for detecting a partial flow blockage in an assembly of a liquid metal reactor through numerical analyses of the temperature fluctuation in the upper plenum of a liquid metal reactor. The developed neural network model for partial flow blockage was based on the changes of the statistical characteristics of the temperature fluctuation data. For analyzing the temperature fluctuation in the upper plenum, we performed numerical analyses with the LES turbulence model in the CFX code and evaluated its statistical parameters. We developed the neural network model with the change of the statistical parameters of the temperature fluctuation data according to the partial flow blockage conditions in an assembly. Through learning and validating the model, we found that the developed neural network model with the fluctuation data in the upper plenum would be a good solution for detecting a flow blockage.

Acknowledgements

This study has been carried out under the Nuclear R&D Program by MOST in Korea.

References

[1] Biserna T. et al, "Results of acoustic and temperature noise measurements on sodium cooled electrically heated 7 rod bundle," Progress in Nuclear Energy, **1**[2-4], 517 (1977).

[2] Haga, K., et al., Experiments on local core anomaly detection by fluctuations of temperature and flow rate at LMFBR fuel subassembly, PNC n941 81-18 (1981).

[3] Jung, J.H. and G.J. Yoo, "Analysis of unsteady turbulent triple jet flow with temperature difference," J. of Nucl. Sci and Eng., **41**[9] 931 (2004).

[4] Ha G.S. et al, "Analysis of flow blockage with MATRA-LMR code," Proceedings of Korean Nuclear Society Spring Meeting, May 29-30, Kyeong-Ju, Korea. (2003).

[5] Moller M., "A scaled conjugate gradient algorithm for fast supervised learning," Neural Network, **6**, 625 (1993).

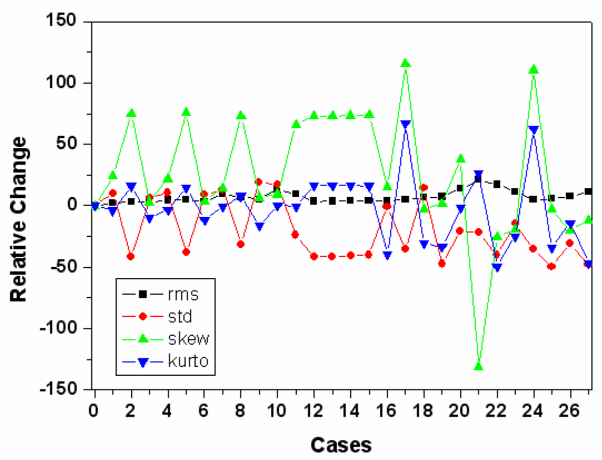


Fig. 1 Statistical Characteristics of Temperature Fluctuation

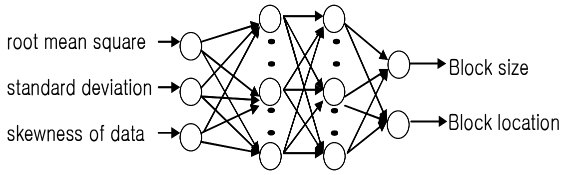
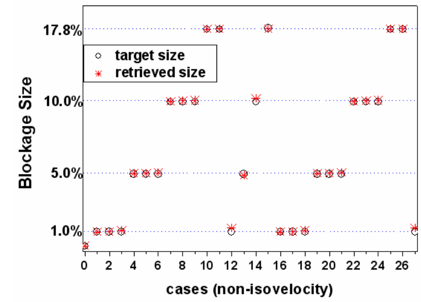
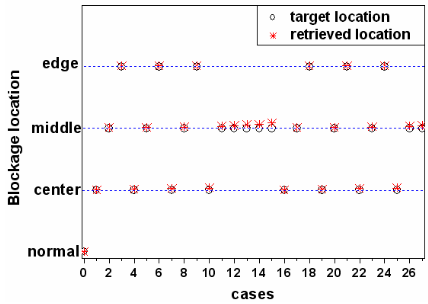


Fig. 8 Structure of neural network model

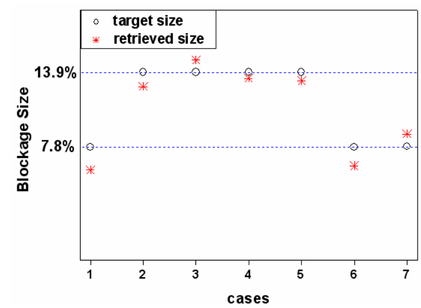


(a) size

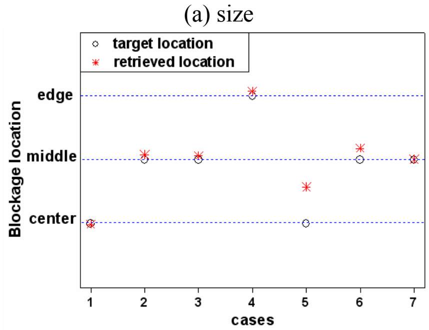


(b) location

Fig. 3 Results of Learning



(a) size



(b) location

Fig. 4 Results of Validation